BIOLOGIZED TECHNOLOGY ELEMENTS IN CONFECTIONERY SUNFLOWER: EFFECTIVENESS ASSESSMENT

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Abstract. This article presents the results of research into the effectiveness of biological control techniques in the cultivation of confectionery sunflowers under arid conditions of the Steppe of Ukraine. Field trials were conducted between 2024 and 2025 using the "Lakomka" variety of confectionery sunflower. The biological control techniques are based on integrated pest and disease management. The set of measures includes: field observations, population monitoring using pheromone traps, agronomic practices, conservation of natural enemies (parasitoids and predators), and biological control (combination of insecticidal and fungicidal biological products, and plant nutrients). The following were assessed: uniformity of emergence, plant vigour, phytosanitary condition of crops, yield, weight of 1,000 seeds, hulling rate, oil content and protein content. It was shown that there were no significant differences between the technologies in terms of seedling emergence, growth vigour, Fusarium wilt infection and soil-borne pests. It was established that the biological control system is capable of keeping the intensity of pest spread and the severity of disease development at a level of economic significance. It is reported that the yield of sunflowers using the biological cultivation method was 0.45 $t \cdot ha^{-1}$ higher than that achieved using the conventional method, which is explained by the development of higher plant productivity compared to the conventional method ‑ 77.6 $g \cdot plant^{-1}$ (16% higher) and 7.4% higher weight of 1,000 seeds ‑ 113.8 g. In terms of hull content, oil content and protein content, the produce grown using organic farming techniques meets the quality standards for confectionery sunflower seeds.

Keywords: confectionery sunflower, pests, diseases, biocontrol, yield.

Introduction

Sunflower (*Helianthus annuus* L.) is among the top three leading global oilseed crops, alongside soybean and rapeseed, and ranks as one of the two most widely cultivated oilseed crops in the European Union together with rapeseed [1]. In recent years, there has been considerable interest in the cultivation of confectionery sunflower varieties. The expansion of their cultivation area is due to high demand, as well as the emergence of new hybrids that meet modern requirements – these are high-yielding, large-seeded genotypes with a 1000-seed weight of at least 100 g and excellent physical and mechanical properties – the seeds are easily dehulled, yielding a clean kernel, with a dehulling coefficient not lower than 0.6-0.7 [2; 3].

At the current stage of global sunflower production, the proportion of varieties and hybrids intended for confectionery use is steadily increasing and currently accounts for around 4-5% of the total area under cultivation. As confectionery sunflowers are consumed directly (after light roasting in confectionery products, as well as in the form of snack seeds), the ecological purity of the seed is of paramount importance. After all, it is in the seed that substances accumulate which enter the plant via water, nutrients and plant protection products, adversely affecting its biological value and taste qualities. This condition particularly highlights the importance of ecologically clean raw materials for confectionery sunflowers [4].

Key factors for successful cultivation of confectionery sunflower include: appropriate selection of varieties/hybrids; high-quality soil (the most suitable are chernozem and chestnut soils with neutral acidity, with an optimal pH of 6.0-7.2); adherence to optimal sowing dates and plant density; balanced application of mineral fertilizers; and effective protection against harmful organisms.

An analysis of scientific articles on the effectiveness of technologies revealed significant variations in the levels of fertiliser and plant protection products. This leads to conflicting results when attempting to identify the best technological solutions.

Serbian scientists from the Centre for the Development of Organic Production (Selenča, Serbia) have proposed the use of the organic fertiliser Guanito in combination with applications of the amino acid-based fertiliser Trainer or the microbiological fertiliser Natur Plasma (based on Chlorella vulgaris) for organic cultivation of sunflowers. The implementation of a technological approach to optimise sunflower plant nutrition ensured an increase in soil biological activity by stimulating its enzymatic activity, enhancing plant immunity to pathogens (Alternaria, Phoma), and increasing the yield by 15-35% whilst improving seed quality and forming the basis for biological cultivation technology [5].

In North America, the development of biocontrol is considered a promising area for biological technologies, specifically: the application of pheromone technologies for sunflower pest management. Considerable attention is being paid to the role of parasitoids (Braconidae, Ichneumonidae, Tachinidae), predators (Orius, Nabis, Chrysoperla) and entomopathogenic fungi. Their use makes it possible to reduce dependence on chemical pesticides [6].

Ukrainian scientists have demonstrated the positive impact of biological products on sunflower productivity; in particular, treating seeds with the mycorrhiza-forming biological product MycoFriend increases sunflower yield by 0.24-0.30 $t \cdot ha^{-1}$ [7]. Optimal timing and methods for the application of mineral, organic, micro, and bacterial fertilizers, as well as biological preparations, have been established. These measures make it possible to normalize the activity of living organisms in the soil, restore the nutrient balance, and promote humus accumulation. This allows for a reduction in energy costs by 12-15%, an increase in yield by 0.2-0.3 $t \cdot ha^{-1}$, and an improvement in the profitability of high-quality sunflower seed production by 15-20% [8].

Certain elements of biologized technology for the cultivation of confectionery sunflower are already being applied in practice. However, a comprehensive biologized cultivation technology for confectionery sunflower has not yet been developed.

The aim of this study is to develop a technology for the cultivation of confectionery sunflower that incorporates full biologization of key technological measures (fertilization system, protection against harmful organisms, and stimulation of growth processes) and to assess its effectiveness.

Materials and methods

The research was conducted at the Research Department of Biological Technologies and Innovative Development of the ITI "Biotekhnika" of the National Academy of Agrarian Sciences of Ukraine on slightly alkaline chernozem (pH 7.44) during 2024-2025, in accordance with standard methodological approaches in crop production using the confectionery sunflower variety *Lakomka*. The biological technology for growing confectionery sunflowers has been developed taking into account the knowledge base regarding diagnosis and prevention, decision-making to combat insect pests and prevent the development of phytopathogens, in accordance with the phases of sunflower ontogenesis, based on: soil improvement through the application of the soil microbiological fertiliser Groundfix (a complex of microorganisms for RK mobilisation and N-fixation); integrated nutrition through the application of the complex biofertiliser Gumifriend (based on potassium humate) and HelpRost Boron, 500 ml; a biological plant protection system against pests and diseases through the application of: bioinsecticides - Metarhizium BT (*Metarhizium anisopliae*), Betsimid BT (*Bacillus thuringiensis* var. *kurstaki*), Beauverin BT (*Beauveria bassiana*) and biofungicides - Vitastim BT (*Trichoderma harzianum* pcs. *Istoksky*, Pseudomonas fluorescens No. 2, Pseudomonas fluorescens No. ARZZ), Biogibervit BT (*Trichoderma viride* No. M-10, *Trichoderma harzianum* No. *Istoksky*), *Coniotirin* BT (based on the *hyperparasitic* fungus *Coniothyrium minitans*). The control treatment was the standard sunflower cultivation method, which involved the application of N30P30K30 during spring cultivation and N16P16K16 at sowing, as well as a combination of the synthetic insecticides Cruiser, KS, Connect, KS and the fungicides Priaxor, KE and Fox, KE. The study was conducted in four replicates.

Indicators analysed to determine efficacy.

- At sunflower growth stage BBCH 10: percentage of plants in the emergence stage, %; percentage of damaged plants in the plot, %.
- At BBCH 12 and BBCH 14: plant "vigour"; percentage of damaged plants in the plot, %.
- At BBCH 18-19, BBCH 30-33 and BBCH 51 stages: disease incidence (prevalence and severity); pest population and plant damage.
- At BBCH 89-99 stage: yield, weight of 1,000 seeds, seed quality.

Product quality was determined at the independent laboratory "Agmintest Control Union" (Odessa), accredited to international standards.

The evaluation of field experiment results was carried out using analysis of variance (ANOVA) [9], specifically assessing aphid infestation of sunflower plants, average seed weight per plant, yield, thousand-seed weight, hull content, and oil and protein content of the seeds. To determine the least significant difference (at 5% level) between different cultivation technologies, replication over two years of research was used.

Results and discussion

Effects on field germination, growth vigour, soil pest infestation, and root rot incidence

The results of the observations showed that soil improvement through the application of the soil microbiological fertiliser Groundfix and seed treatment with a tank mix comprising the biofertiliser Humifriend, Metarizin BT bioinsecticide and Vitastim BT biofungicide ensured a field germination rate of 93.4%, compared to 95.5% for the controL.

No significant difference was observed between sunflower cultivation technologies in terms of plant growth "Vigour" (VIGOUR) at the BBCH 12-14 stage, which was rated at 8 points (good plant condition); no damage to plants by soil pests was noted. No significant difference was recorded between cultivation technologies in terms of Fusarium wilt incidence.

Leaf-feeding pests. Pests of the flower head

The basis for developing plant protection measures in crop cultivation technology is the assessment of the phytosanitary status of the agrocenosis. Based on monitoring studies of the phytosanitary status of the sunflower agrocenosis during the growing season, we have identified two main groups of phytophages: leaf-feeding pests and flower head pests. For each group, activity phases and control methods have been determined. The first half of the growing season is characterized by the infestation of sunflower crops by sucking pests, primarily aphids, specifically the helichrysum aphid (*Brachycaudus helichrysi Kalt*.), and in southern regions, whiteflies (*Aleyrodidae*). At sunflower development stage BBCH 18, the onset of infestation by herbivorous bugs is observed: the species being the field bug (Lygus pratensis L.), and, from the flower bud development stage (BBCH 51-59), by bugs belonging to the families Pentatomidae and Coreidae, as well as the first colonies of the beetroot aphid (*Aphis fabae Scop*). Using pheromone monitoring, from the flowering stage (BBCH 65) onwards, the emergence of cotton leafroller moths has been recorded.

An analysis of data on the infestation of sunflower plants by phytophagous insects has revealed that, during the macroscopic stage - specifically the development of leaves, plant growth in height and flowering - insects with a sucking mouthpart predominate; during the macroscopic stage of development and ripening of the flower heads and seeds, the cotton bollworm (Fig. 1).

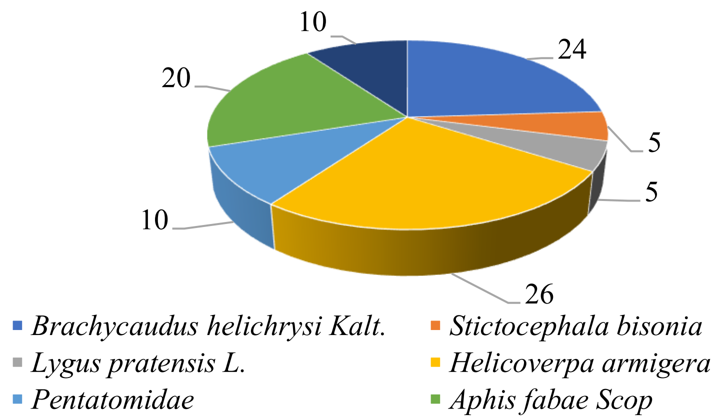


Fig. 1. **Status of the phytophagous insect population in confectionery sunflower crops grown using biological cultivation techniques, population of plants, %**

Diseases of the leaves, stems and flower heads

The phytopathogenic complex of the confectionery sunflower agrocenosis during the leaf development and stem growth stages is characterised by leaf spot diseases (Fig. 2).

- During the leaf development phase (BBCH 18-19), the first signs of infection with Alternaria leaf spot (caused by the fungus Alternaria alternata (Fr.)) and Phoma leaf spot (caused by the fungus Phoma oleracea Sass) were observed. The prevalence of the diseases varied slightly depending on the cultivation techniques. Phomosis appeared almost simultaneously and was prevalent at 6.7% under the biological control system and 9.1% under the conventional system. The first symptoms of Alternaria leaf spot were observed in crops where chemical control was applied, with an infection rate of up to 5%. Subsequently, the progression of the diseases was moderate, with a gradual increase from the lower to the middle leaf tier. We note that phomosis develops more actively under the organic system, whilst Alternaria develops more actively under the conventional system;
- During the flowering stage (BBCH 61-65), symptoms of rust infection were observed on the upper leaves; the causative agent is the fungus Puccinia helianthi Schw. and we detect isolated cases of sclerotinia stem rot (stem form, caused by the fungus Sclerotinia sclerotiorum) and the presence of sunflower broomrape (Orobanche cumana). We note that under organic farming practices, the prevalence of sunflower broomrape was half that observed.

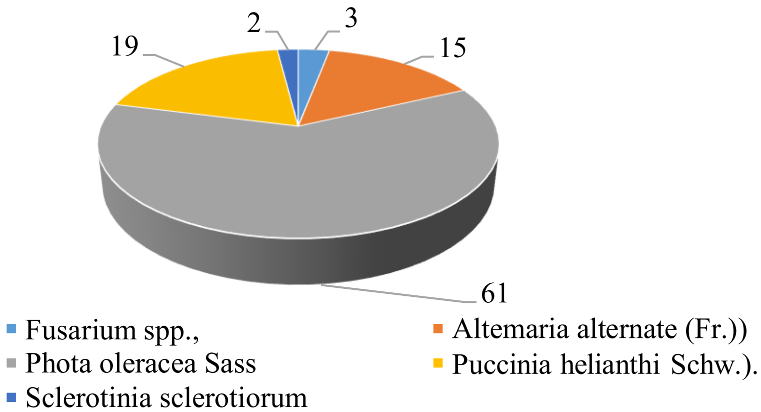


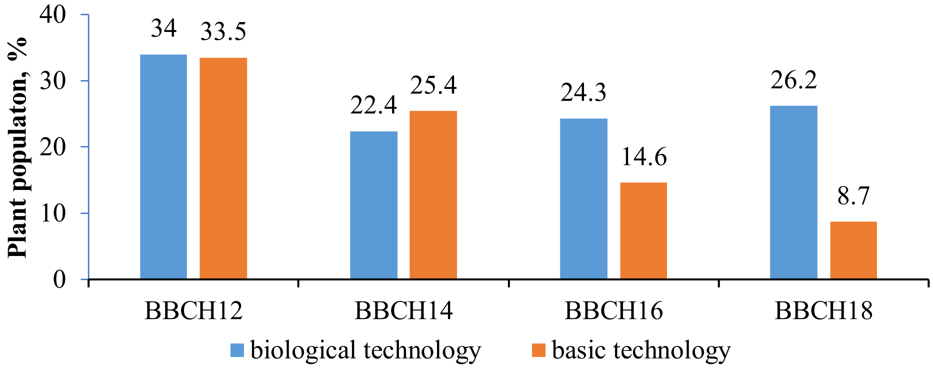
Fig. 2. **Phytopathogenic complex of confectionery sunflower crops grown using biological cultivation techniques during BBCH 18-71 stage (disease prevalence), %**

The most telling period for assessing the effectiveness of cultivation techniques is the seed formation and ripening stage, as it is during this macro-stage of sunflower development that head diseases pose a particular threat; these diseases not only reduce yields but also lead to a deterioration in product quality. In the southern regions of Ukraine, brown dry rot of the flower heads has been spreading most intensively in recent years, due to positive temperature anomalies; the causative agent of the disease is fungi of the genus Rhizopus. Infection of flower heads by white rot (sclerotinia) and phomosis has been observed, but with a relatively low degree of infection (up to 5%).

Biological control

The biological plant protection system involved two spray applications to the crops against leaf-feeding pests and leaf spot diseases, and two spray applications against pests and diseases of the flower heads using tank mixes containing bioinsecticides and biofungicides.

The first control measure against sucking pests was carried out at the onset of aphid infestation on sunflower plants, preventing the formation of colonies. Under the conventional method, treatment was carried out with the insecticide Engio ($0.18\ l \cdot ha^{-1}$), whilst under the biological method, it was carried out with the bioinsecticide Metarizin BT ($2\ l \cdot ha^{-1}$). An analysis of the products' efficacy showed that the bioinsecticide Metarizin BT provided protection for 10 days, preventing the active spread and infestation of plants by aphids, which remained within the range of 22.4-24.2%, compared to 14.6-8.7% with the standard method. The efficacy of biological preparations on the 14th day after treatment was 23%, whilst that of chemical preparations was 74% (Fig. 3).



	BBCH12	BBCH14	BBCH16	BBCH18
$HIP_{0,95}$	2.45	2.02	2.11	1.68

Fig. 3. **Influence of confectionery sunflower cultivation technologies on the population of sunflower plants with aphids**

It is important to note that in the plot where the biological control system was applied, there was a fairly active colonisation of sunflower plants by entomophages (*Chrysopa perla*, *Coccinella septempunctata*, *Syrphus rebesii* L., *Ophion luteus*), which significantly limited the active reproduction and subsequent colonisation of the plants by aphids. This fact demonstrates the real impact of microbiological preparations and entomophages on the population dynamics of pests in the agrosystem of confectionery sunflowers. Our findings are consistent with comprehensive studies in the USA and Canada on sunflower pest management, which place significant emphasis on the role of parasitoids (*Braconidae*, *Ichneumonidae*, *Tachinidae*), predators (*Orius*, *Nabis*, *Chrysoperla*) and entomopathogenic fungi. Their use makes it possible to reduce dependence on chemical pesticides [10].

The second treatment against leaf-feeding pests and leaf disease pathogens was carried out at sunflower growth stage BBCH 18 using a tank mix of HelpRost Boron + Gumifriend liquid + the bioinsecticide Becimide (w.m.) + the biofungicide Biogibervit BT (w.m.); the third – at the BBCH 30 stage with a tank mix: biofungicide Vitastim BT (w.s.) + bioinsecticide Metarizin (w.s.) + bioinsecticide Bovein (w.s.). On the third day after treatment, we observe complete aphid mortality in the plot treated with the biological technology and isolated colonies of the pest in the plot treated with the conventional technology. The development of diseases (phomosis and alternariosis) is practically at the same level (10.0-11.5% with the biological technology and 13.1% with the standard technology). The fourth and fifth treatments were carried out to protect the flower heads from harmful organisms using tank mixtures: HelpRost Boron + Gumifriend w.m. + biofungicide Coniotirin BT (w.m.) + bioinsecticide Becimide (w.m.) at development stage BBCH 51; HelpRost Bor Universal + biofungicide Coniotirin BT (w.s.) at BBCH 59 stage. Pheromone monitoring revealed that cotton bollworm moths appeared seven days after treatment, with the first signs of caterpillar feeding on sunflower heads observed after 21 days. The percentage of plants infested by the pest at the end of flowering (BBCH 67-69) was 26% under the biological control system and 23% under the chemical control system.

Analysis of disease progression trends revealed that the measures taken curbed their spread, specifically: the first signs of flower head infection were observed at the end of flowering (BCH 65-67), followed by a moderate increase during BCH 71-73, reaching 56% with the biological approach and 44% with the conventional approach.

Thus, the set of biological measures implemented makes it possible to control the growth in pest populations and the prevalence of diseases, and consequently the actual level of plant damage, which is directly linked to the yield.

Assessment of economic efficiency

Analysis of yield data provides grounds for asserting that, under the organic cultivation technology, plant productivity is higher (by 16%) and the weight of 1,000 seeds is greater (by 7.4%), which, together with the effectiveness of biological control measures, makes it possible to achieve an additional yield of 0.45 $t \cdot ha^{-1}$. Analysis of product quality indicates that, in terms of hull content, oil content and protein content, the product grown using organic farming techniques meets the standard quality requirements for confectionery sunflower seeds, Table 1.

Table 1

Indicators of productivity and quality of confectionery sunflower varieties Lakomka with different cultivation technologies

Growing technology	Average seed weight per plant, g	Biological yield, t·ha^{-1}	Supplement yield, t·ha^{-1}	Weight of 1000 seeds, g	Huski ness, %	Oil content, %	Protein content, %
Biologized	77.6	2.71	0.45	113.8	27	43.96	16.5
Basic (control)	64.6	2.26	-	105.4	26	45.95	17.53
$HIP_{0,05}$	6.73	0.23	-	9.87	2.24	4.42	1.53

Statistical analysis of the research results indicates that, across a set of indicators, the biologized cultivation technology is not inferior in effectiveness to the conventional (baseline) technology.

In our opinion, product quality will be more significantly influenced by the growing regions and their climatic characteristics; specifically, in the southern growing zone, confectionery sunflower seeds will accumulate a higher percentage of protein and a lower oil content. In the Forest-Steppe zone, we will see the opposite situation – protein content decreases, whilst oil content increases.

Conclusions

1. It was established that the use of multicomponent microbiological preparations for plant nutrition, as well as pre-sowing seed treatment with a tank mixture of preparations (biofertilizer + bioinsecticide + biofungicide), mitigates the impact of adverse weather conditions, unbalanced plant nutrition, and insufficient protection, ensuring plant growth energy comparable to that achieved under the baseline technology.
2. It was demonstrated that the foundation of the biologized technology is integrated pest and disease management. The set of measures includes field observations, population monitoring using pheromone traps, conservation of natural enemies (parasitoids and predators), and biological control, which involves combining microbiological preparations with insecticidal and fungicidal action with integrated plant nutrition. This approach enables control over the increase in phytophage populations and disease spread, thereby maintaining actual plant damage at an economically acceptable level.
3. The yield increase resulting from the application of the complex of biologized technology elements reached 0.41 t·ha^{-1}, which is explained by higher plant productivity – 77.6 g per plant (an increase of 16%) – and a greater thousand-seed weight (by 7.4%).
4. The products obtained using the biologized technology comply with the standard quality indicators for confectionery sunflower.

Author contributions

Conceptualization, O.O.; methodology, O.O., Ye.H., I.G., V.K. and N.P.; software, Ye.H., I.G., V.B. and I.I.; research, O.O., I.G., V.K., Ye.H., N.P. and I.I.; organize your data, Ye.H., V.K., N.B., V.B. and I.I.; preparation of the initial project, O.O., Ye.H.; writing - reviewing and editing, O.O., A.R. and A.A.; visualization, I.I. All authors have read and agreed with the published version of the manuscript.

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